KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

ELECTRICAL ENGINEERING DEPARTMENT

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EE 360

MAJOR EXAM # 2

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6:30 - 8:00 pm

Key Solution

Section:

Student Name:

Student I.D.#

Serial #

Question # 1	
Question # 2	
Question # 3	
Total	

Q. 1) A 100-kVA, 2300/230-V, single-phase transformer has the following parameters:

$R_1 = 0.30$ ohm $\quad X_1 = 0.65$ ohm $\quad Rc = 4.5$ k-ohm

$R_2 = 0.0030$ ohm $\quad X_2 = 0.0065$ ohm $\quad X_m = 1.0$ k-ohm

The transformer delivers 75 kW at 230 V and 0.85 power factor lagging. Determine

a. The input current

b. The input voltage

c. The input power and power factor

(30 Marks)

Solution:

$$V_2 = 230\angle 0^\circ \ V$$

$$I_2 = \frac{75{,}000}{(230)(0{,}85)} \angle -\cos^{-1} 0{,}85 = 383{,}63 \angle -31.8^\circ \ A$$

$$a = \frac{2300}{230} = 10$$

ⓐ $$E_1 = aV_2 + \frac{I_2}{a}(a^2 R_2 + j a^2 X_2)$$

$$= 10(230\angle 0) + \left(\frac{383.63}{10}\angle -31.8^\circ\right)(10)^2(0.003 + j0\,0065)$$

$$= 2322.9 + j15.1 = 2322.97 \angle 0.37^\circ \ V$$

$$I_1 = \frac{I_2}{a} + E_1\left(\frac{1}{R_c} + \frac{1}{jX_m}\right) = \frac{383.63}{10}\angle -31.8^\circ + E_1\left(\frac{10^{-3}}{4.5} + \frac{10^{-3}}{j1}\right)$$

$$= 33.14 - j22.54 = 40.08 \angle -34.2^\circ \ A$$

ⓑ $$V_1 = E_1 + I_1(R_1 + jX_1) = 2322{,}97\angle 0{,}37^\circ + (40{,}08\angle -34.2^\circ)(0{,}3 + j0.65)$$

$$= 2347.5 + j29.78 = 2347.7 \angle 0.73^\circ \ V$$

ⓒ $$P_1 = V_1 I_1 \cos\theta\Big]_{I_1}^{V_1} = (2347.7)(40{,}08)\cos(0\,73 + 34.2)$$

$$= 77.15 \ kW$$

$$PF = \cos(0.73^\circ + 34.2^\circ) = 0{,}82 \text{ lagging}$$

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Problem 2

A 20-hp 240-V series dc motor has an internal series resistance $R_A + R_s$ equal to 0.25 ohm. At full load, it draws 80 A and runs at 750 r/min.

a. What is the efficiency of the motor at full-load conditions?

b. Assuming that the flux at 30 A is 52 percent of the full-load flux, what is the speed of the motor at a line current of 30 A?

(30 Marks)

Solution:

(a) At full load, the internal generated voltage of this motor is

$$E_A = V_T - I_A(R_A + R_S)$$

$$E_A = 240\ \text{V} - (80\ \text{A})(0.25\ \Omega) = 220\ \text{V}$$

The output power of the motor is

$$P_{OUT} = (20\ \text{hp})(746\ \text{W/hp}) = 14920\ \text{W}$$

The input power to this motor is

$$P_{IN} = V_T I_L = (240\ \text{V})(80\ \text{A}) = 19200\ \text{W}$$

The efficiency of this motor at full load is

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100\% = \frac{14920\ \text{W}}{19200\ \text{W}} \times 100\% = 77.7\%$$

(b) At 30 A, the flux is 52% of the full-load flux, so the internal generated voltage E_{Ao} at a speed of 750 rev/min will be

$$E_{Ao} = (0.52)(220\ \text{V}) = 114.4\ \text{V}$$

The actual internal generated voltage is

$$E_A = V_T - I_A(R_A + R_S) = 240\ \text{V} - (30\ \text{A})(0.25\ \Omega)$$

$$E_A = 232.5\ \text{V}$$

The actual speed of the motor when it is drawing 30 A is

$$n = \frac{E_A}{E_{Ao}} n = \frac{232.5\ \text{V}}{114.4\ \text{V}} (750\ \text{rev/min}) = 1524\ \text{rev/min}$$

Problem 3

A 3-phase, 60 Hz, 6-pole, Y-connected synchronous generator has a synchronous reactance of 4 Ohm and a terminal voltage of 2300 V. The field current is adjusted so that the excitation voltage is 2300 V at a power (torque) angle of 15^o . Neglect the armature resistance and rotational losses,

a. determine the stator current.
b. determine the power factor.
c. determine the output power.
d. determine the torque required to drive the machine.
e. is the machine supplying or absorbing reactive power.

(40 Marks)

Solution:

$$V_t = \frac{2300}{\sqrt{3}} = 1327.9 \ \angle 0^o \ \text{V}$$

$$E_a = \frac{2300}{\sqrt{3}} \angle 15^o = 1327.9 \ \angle 15^o \ \text{V}$$

(a) $I_a = \dfrac{1327.9\angle 15^o - 1327.9\angle 0^o}{j4} = 86.7 \ \angle 7.5^o$

(b) PF = $\cos 7.5^o$ = 0.991 Leading

(c) $P_{out} = \dfrac{3(1327.9)(1327.9)}{4} \sin 15^o$ = 342.28 kW

(d) $n_s = \dfrac{(120)(60)}{6}$ = 1200 rpm

$w_m = \dfrac{2\pi(1200)}{60}$ = 125.7 rad/sec

$T_{shaft} = \dfrac{342.28}{125.7}$ = 2.72 kN-m

(e) The machine is absorbing reactive power.